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THERMOPLASTICS IN APPLIANCE DESIGN

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It is safe to say all household appliances employ thermoplastics today. These thermoplastics appear as decorative, structural, or functional items, as insulation, or as incidental parts; and while they are obvious or visible in most cases, they are not always in plain sight. Most of these plastics, if they are considered by statistical numbers, are well accepted, trouble-free, and unnoticed.

Some of the plastics, mainly structural, are of recent adaptation; and these applications are the ones which have received conspicuous attention. The manufacturing economy and sales appeal of these new applications are overwhelming factors in promoting continued use, in spite of some presently-encountered difficulties. The difficulties have been brought to the door of the product engineering department in nearly every appliance factory, and this appears to be an appropriate place to bring such problems for solving.

Solving problems of plastics applications is mainly an engineering function whether the problems are materials selection, product design, tool design, quality control, or manufacturing processing. The engineering department in the appliance factory has most of the equipment which is required to solve these problems, and it is only logical the problems should be taken there for solution.

The Role of the Appliance Engineer as a Problem Solver

The appliance engineer is the responsible person for engineering functions. This includes the individual engineer as well as the department itself or the department head. School work and a professional degree are the standard engineering preparations for the work of the appliance engineer. Supplementary knowledge and skills must be added to the standard preparation, and it is a professional obligation of each engineer to acquire them somehow.

The present trend in manufacturing appears to spotlight the engineering department as the key to solving the technical problems of industry. Possibly, it would be more appropriate to say the technical problems of industry have been spotlighted as the key to industrial progress.

Industry's problems are not all technical, however, and the engineering department is not any more the hub of the universe

than accounting, legal, sales, purchasing, or manufacturing departments have been in their turns which they have had at various times. The engineer must recognize his responsibility and the true weight of engineering in the summation of all factors which are represented by the bill of lading and the invoice for the finished goods shipped. Recognition of his position, and action appropriate to this position, is possibly half of the engineer's task today. His technical knowledge and skill can be wasted unless he employs them in positive action and with confidence in the importance of his work.

The importance of spending considerable time and effort in the engineering department to learn the fundamentals of design of components for appliances cannot be overstressed. Such information is not a part of regular college courses, and it has to be acquired through supplementary learning in some fashion. Books, pamphlets, and bulletins are available to tell various parts of the story, but there isn't any complete text book yet. It has been difficult for the engineer to know which facts are of importance and which are of minor interest because so many have been distributed and in such a piecemeal fashion. There seems to be no well-rounded organization of a technology of component design for plastics in appliances in view at the moment, but it is not too early to aim in that direction.

The product designer needs to know the realistic properties of the plastic materials which he is specifying. He needs to know the effects of fabrication upon the inherent realistic properties of the materials, and he needs to know something about how the tools are made to fabricate the finished product.

Recent Trends in Technical Knowledge

Thermoplastic materials are being employed as load-bearing members of household appliance structures more and more. A few examples are as follows:

- Refrigerator door liners to stiffen the door structure.
- Refrigerator door shelves to carry 20 to 40 pounds of working load.
- Television fronts to stiffen the cabinet's structure rather than merely to serve as a trim mask.
- Television safety shields rather than a diffuser to make the viewing more pleasant.
- Radio cabinets with integral mounting studs.
- Floor cleaner tank bodies.
- Refrigerator door handles.

There are many other applications of thermoplastic materials as load-bearing members. There is no need to list more than a few typical ones.

The physical properties of the plastics are subject to relatively wide changes due to ambient conditions of:

- Temperature.
- Continued Load versus Time.
- Moisture.
- Chemical Exposure.
  (Air is a kind of chemical, and cleaning compounds are chemical reagents also.)

The effects of environmental conditions are being cataloged by plastics manufacturers, and many details are available in their books and bulletins, as well as from their representatives in person. The complete catalog is rather large at the present time; and for this reason, it is well to look first at some fundamentals which will serve to outline the sections rather than to examine the individual pages too closely.

Definitions of Types of Data Available

Three kinds of data have been available traditionally from suppliers of any kind of raw materials including plastics. The chief data on plastics have been in these three types.

Identity	Screening	Quality Control
Data used to identify grade, type, purity, or composition of a product among otherwise similar products.	Data which ranks similar products or materials in order of preference of a given characteristic.	Data relating to predetermined levels of acceptable quality.

None of these types of data tell very much about the materials when they are put to work in a functional manner. Designers have tried to use such data in establishing product designs and manufacturing processes for some time, and they have had to apply safety factors which are much more of a guess than they are a calculation of risk.

The guesses and safety factors were very poor in some cases. Furthermore, not very many people stopped to think about this;

and as a result, scarcely anyone designed to meet an expected stress nor attempted to determine what stresses might be encountered by structural plastic parts in household appliances.

The data which are actually needed for design of structural plastics parts are in the following two classifications.

Engineering	Design
Data relating to the intended performance of a component regardless of the material from which it is made.	Data which provides a basis of realistic properties for calculating size and shape required for satisfactory performance.

Identity, screening, or quality control data are traditionally selected for maximum convenience of standardization and minimum costs to obtain them. Figure 1 shows the location of a point in space which represents the tensile strength of polystyrene tested at "standard" conditions. Use conditions may not equal the standard conditions in any application at all. Recent work during the past two years has been concentrated on establishing the "surface" of test values so design data may be derived.

Design Data

Failures of structural parts always occur in tension, and several schemes for studying tensile strength behavior of plastics have been established. It is not necessary for tensile failure to be an actual rupture. Gross deformation is also a failure. This leads to a study of creep and relaxation as a means of learning the inherent design properties of thermoplastics. Creep is deformation under constant load, and relaxation is decay of force at constant strain.

The modulus of elasticity is a simple idea when it is understood to be the quotient of stress divided by strain. However, it is not so simple to determine which value of stress is to be divided by which value of strain. Creep and relaxation tend to change the modulus figure with time. The time dependent modulus has been called "apparent modulus," and it is much more significant design data than the instantaneous modulus which is ordinarily reported because the apparent modulus is the measure of the true stiffness of the material.

Some apparent moduli have been determined for time periods up to 100,000 hours as shown in Figure 2. The materials are as follows:

SAN = Styrene acrylonitrile copolymer
PMMA = Polymethyl methacrylate
MPS = a Rubber modified polystyrene
PFM = a Polyformaldehyde resin
NYL = a Nylon resin
PE-I = a Type I polyethylene

The elastic modulus varies with temperature as it would ordinarily seem to be reasonable. Figure 3 shows some temperature effects on various plastics. There is some difference in the characteristic behavior according to the kind of thermoplastic which is involved, and the shapes of the curves indicate there may be some food for thought in this respect.

It requires considerable testing time to determine the three-dimensional relationship of modulus with time and temperature. Some predictions can be made, however, on the basis of the two curves which have been presented, and these predictions are likely to be much better than using the quality control standard data for design.

Similar treatment of other properties of thermoplastics is going on. For example, Figure 4 shows the effect of environment upon some plastics over long periods of time. Much more chemical resistance data is becoming available but the noteworthy thing is a long period of time seems to be required to establish equilibrium conditions.

The form stability of thermoplastic structures at elevated temperatures is a very important matter to appliance designers. Early tests to determine heat distortion temperatures have been used to report data on the single point in space system, and this is not very satisfactory for design information. Figure 5 shows some deflection temperatures as a function of fiber stress. The fiber stress has a considerable effect upon the temperature at which the plastic deflects a given amount under the test conditions. Crystalline plastics such as polyethylene have relatively high instantaneous heat distortion temperature at low or no load. However, when the fiber stress is increased, the heat distortion temperature drops rather rapidly. Appliance parts are not always subject to conditions of no load; and when they are loaded, the amount of their deflection is often a surprise. It must not be a surprise to the design engineer who has to be aware of the effect of fiber stress.

There are many projects going on among material suppliers and appliance users to determine the properties of plastics materials in a form in which they are useful for design data. At the present time, this large area of data is not filled in very completely, and it is necessary to rely upon experience and judgment to a considerable extent. However, work is progressing rapidly, and considerable gains are being made in obtaining much more useful data.

Effects Upon the Properties Due to Fabrication Conditions

The impact strength of thermoplastics is an important property in design of structures. The inherent impact strength is not always obtainable because the method of fabrication usually produces some orientation. Figure 6 shows the impact strength of a rubber-modified polystyrene measured by falling missile and by the Izod standard machine as the plastic temperature changes. The injection molding process produces orientation lengthwise of the test bar and, inasmuch as the Izod machine tests the plastic longitudinally, the colder material which is more highly oriented shows much higher impact strength than the hot material which has reduced orientation properties.

The falling missile attacks the weakest part of the plastic item and causes oriented materials to split wherever the axis of orientation is. This is different from the Izod material which tests the bar in its strongest direction. Injection molded articles which are molded with high degree of orientation show relatively low falling ball impact strength. As the plastic temperature increases with a resulting decrease of orientation, the impact strength becomes better. The falling missile is more likely to approximate use conditions of a structural part subjected to an impact blow than is the Izod test.

The illustration here indicates higher plastic temperatures are more likely to produce parts having better impact strength. This is not necessarily the only way to improve impact strength because orientation may be reduced in other ways than having the plastic temperature high.

Figure 7 illustrates another interesting characteristic of polystyrene. In this figure, impact strength by the Izod test is measured on injection molded test bars, 1/8 inch thick and 1/2 inch thick, as well as on compression molded bars, 1/8 inch thick. The compression molded bar shows no change of impact strength with cylinder temperature. This is because there is

practically no orientation in the part, and the Izod test does not detect any difference in strength no matter what the plastic molding temperature is.

The bar which is 1/2 inch thick is so thick the oriented skin has very little effect upon the overall strength of the test bar and, therefore, the Izod impact strength shows practically no variation with molding temperature. However, the injection molded bar is not as high in impact strength as the compression molded piece.

The curve for the injection molded bar, 1/8 inch thick, is also presented in this view the same as it was in the previous illustration, and this curve provides an entirely different idea of the impact strength.

It is necessary for the designer to know what the fabrication conditions are likely to do to modify the inherent properties of the plastic. It can be said injection molding cold plastic should be expected to produce extremely good impact strength as proved by these curves. This is true provided the loading and service use of the component is such that the stress is applied where the strength of the plastic is high. However, stresses have to be expected in any and all directions. The Izod test on the injection molded bar is in the direction of greatest strength, and it does not point out the weakest part of the structure.

Practical Fabrication Information

A few rules of design should be observed for making parts of good appearance and making them relatively easy to produce. Figure 8 shows some rib and radii design standards which are recommended to do away with the problems shown in the same view for designs which are not recommended.

Ribs should be made somewhat thinner than the wall to which they are attached to avoid sink marks. Omission of large fillets where ribs meet walls is necessary because the fillet radius must be added to the thickness of the rib to arrive at a figure which is the effective thickness of the rib.

Sharp corners ~~as shown in the right-hand view~~ are not recommended because they produce high stress concentration. Rounded corners are much better when they can be accepted by the styling departments.

+ graphs

Figure 9 illustrates an accumulation of poor part designs in one synthetic view of a container. The most conspicuous part of this illustration is the large bulb at the rim of the container at the parting line. This is a very difficult cross section to fill because the plastic will run all the way around the rim, and then there will be very little opportunity for air to be vented from the mold at the parting line because the plastic has sealed it off. The thick boss with 3/8 inch dimension subtends a relatively thinner 1/4 inch thick wall. This is aiming for a sink mark, if indeed the part can come out of the mold with the negative draft of two degrees. The letters are fairly deep and sharp, and the general cross section varies in thickness far too much for easy mold filling.

Figure 10 illustrates a much improved design for the same part. It has a thinner wall section, and the thickness is uniform all over. The heavy bulb around the rim has been eliminated, and the heavy boss has been cored out to reduce the tendency for sink marks to occur. A considerable amount of draft has been allowed to help the part be released from the mold readily.

The errors and corrections in Figures 9 and 10 are relatively old and well known, but it is surprising how often these errors are found in today's designs. Custom molders recognize these errors in estimating and quoting the mold cost. However, they are often reluctant to suggest changes because the situation is highly competitive, and they do not wish to mention things which may be considered to be unpleasant and could possibly result in loss of a job. The engineering department has a very important function in helping the custom molder to provide good fabrication practice by listening well to his suggestions and by learning enough of the tooling and fabricating business to have a critical understanding of what the vendor is trying to say. Very few vendors are incompetent, and they do not often deliberately try to cheat their prospective customers. The engineering department needs to go beyond the step of product design far enough to understand something about the tooling and the effect of the tooling upon the properties of the finished part.

Summary

Technical information for the design of thermoplastic components of appliances is not a simple matter. It requires careful study, and at the present time it requires the design engineer to look farther than the corner of his drafting board to determine the information he needs. This is a formidable task, but work is going on to make this technical information available in a form which can be adapted readily for engineering use.

The engineer has a further obligation in addition to acquiring the technical knowledge and using it properly. He should be looking toward his overall responsibility in the total manufacturing structure of today's industry. It is not sufficient to design the product and prepare the complete set of blueprints to turn over to manufacturing. It is necessary to follow up with counseling for all other departments and to participate appropriately in the decisions which have to do with the overall operations of the factory. This is a responsibility which should not be taken lightly.

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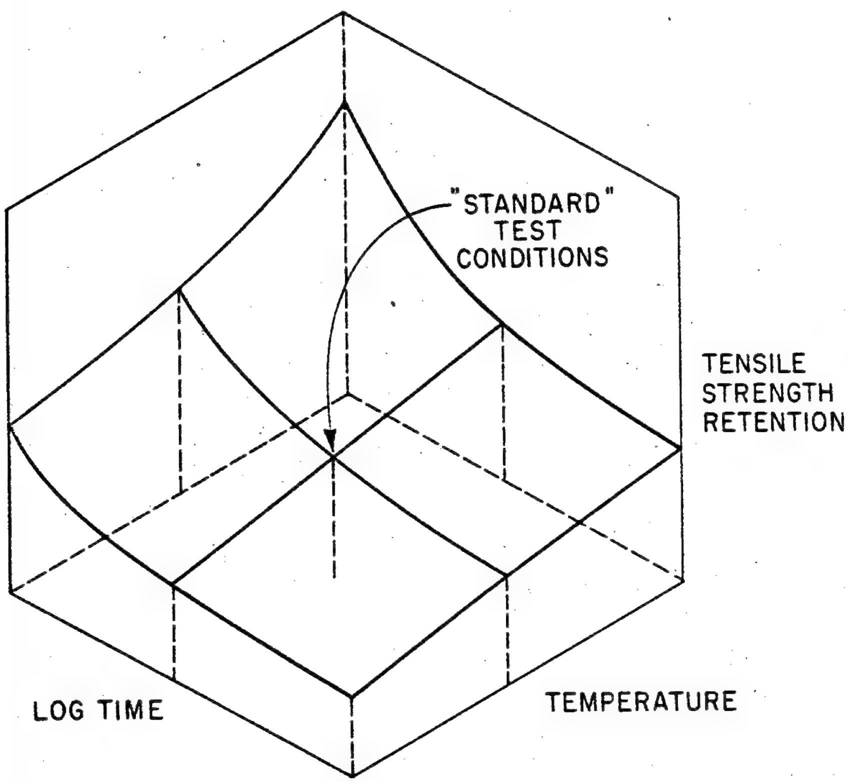

Figure 1

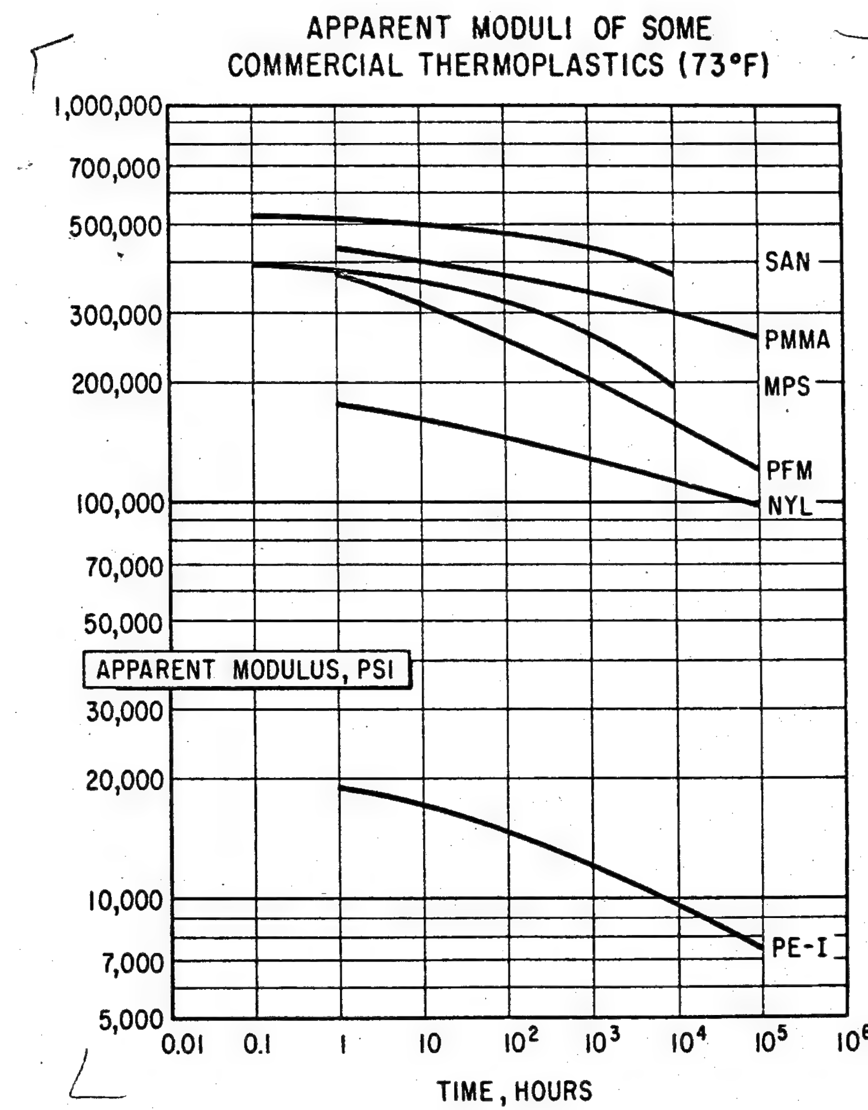

Figure 2

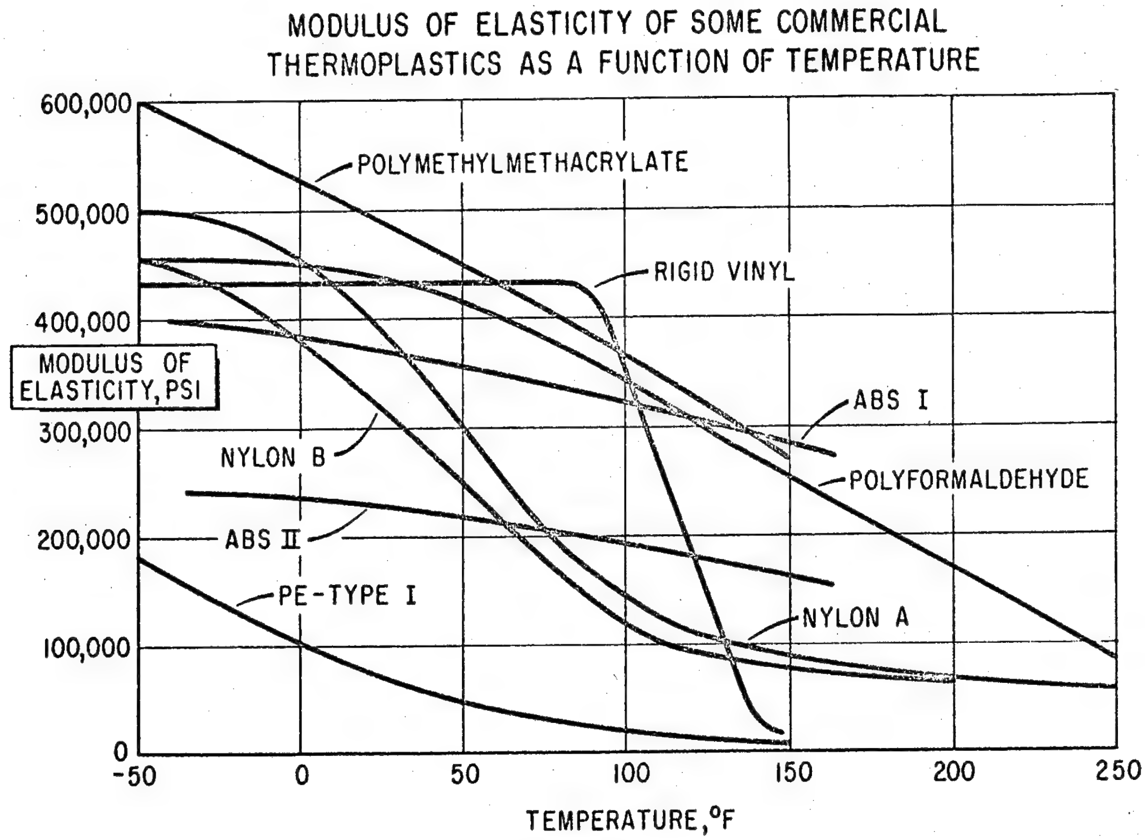

Figure 3

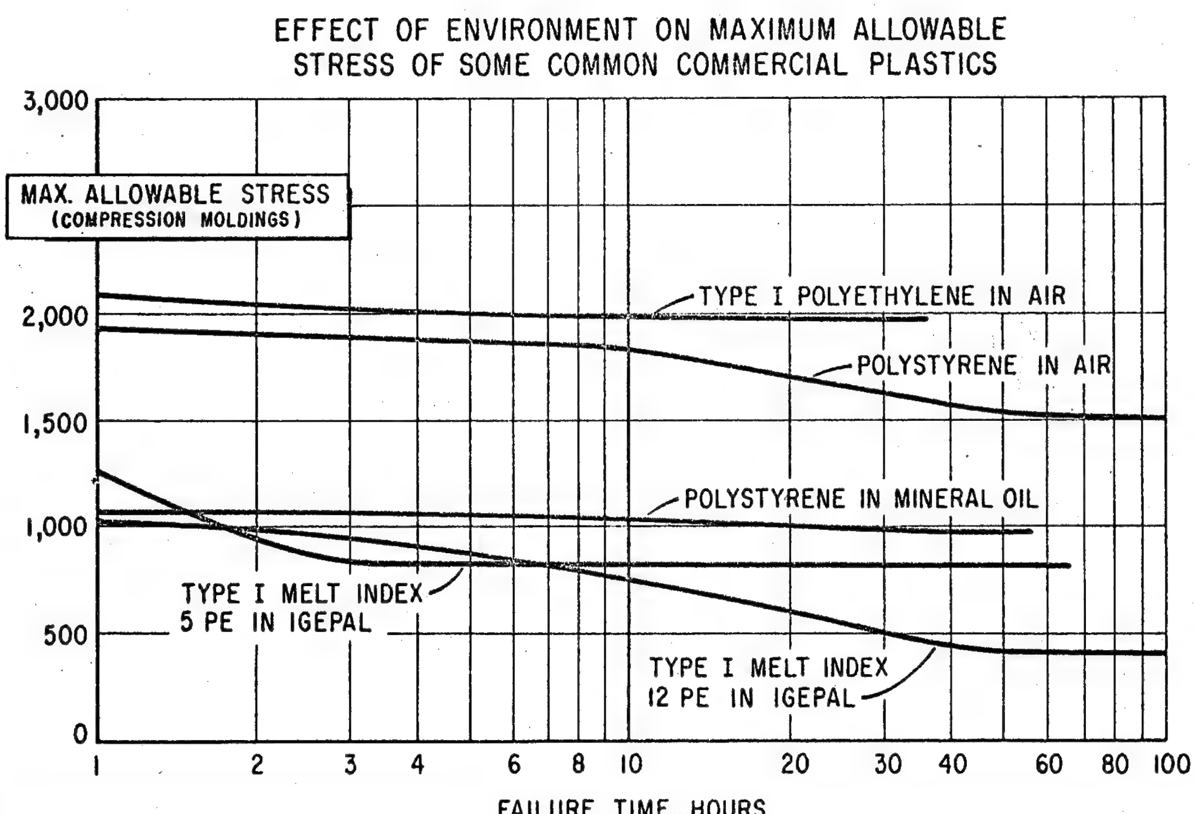

Figure 4

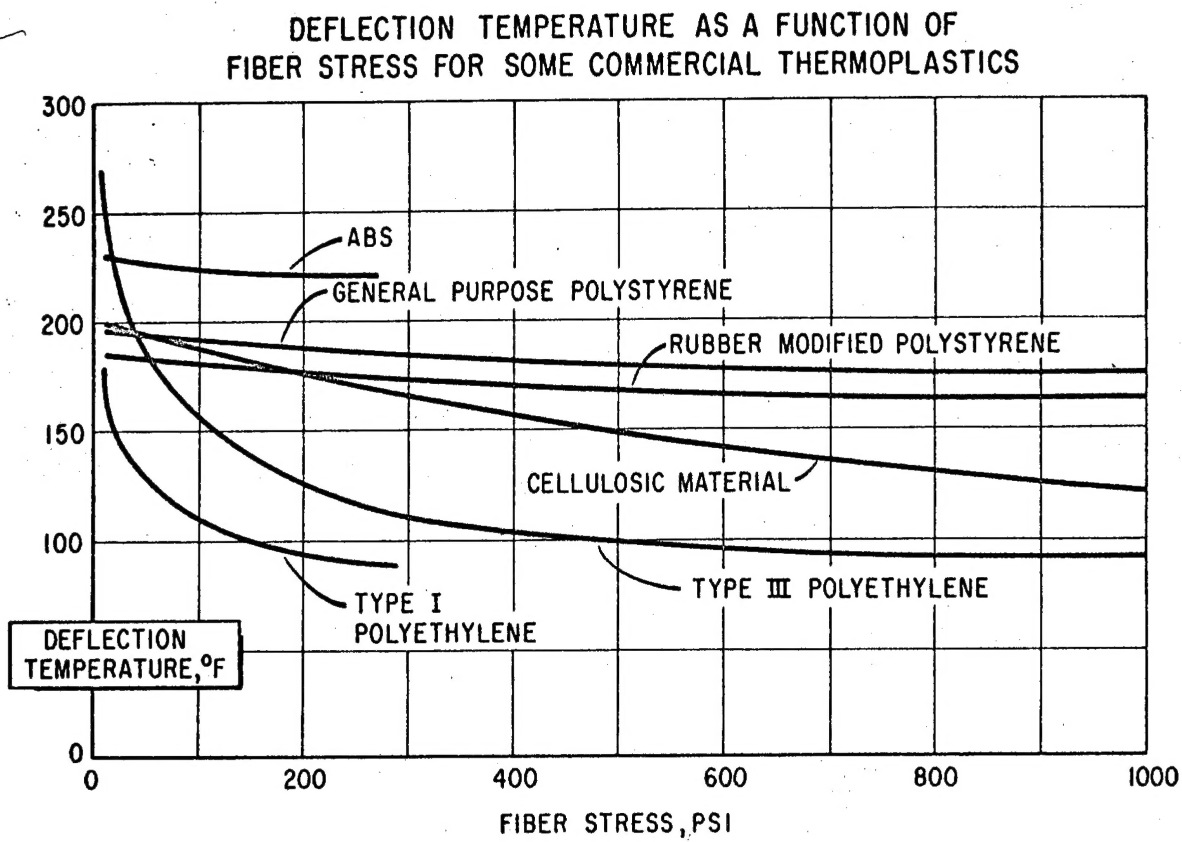

Figure 5

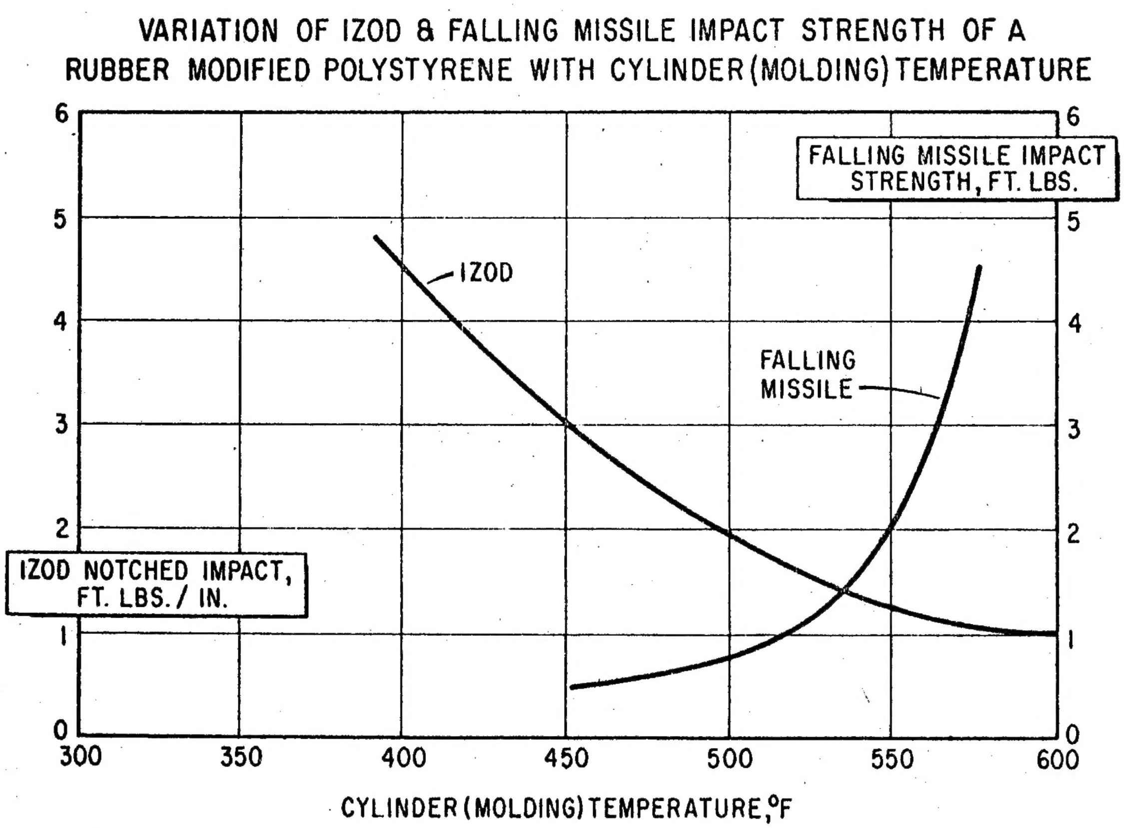

Figure 6

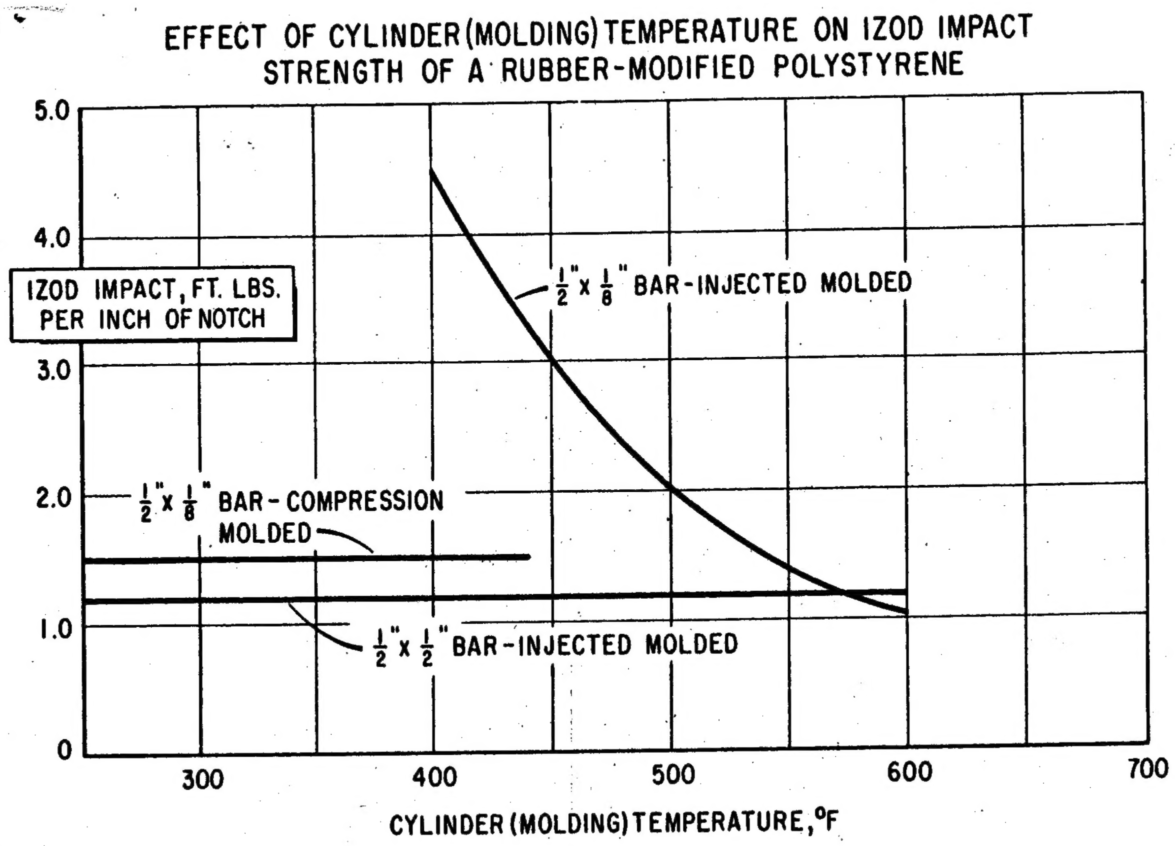

Figure 7

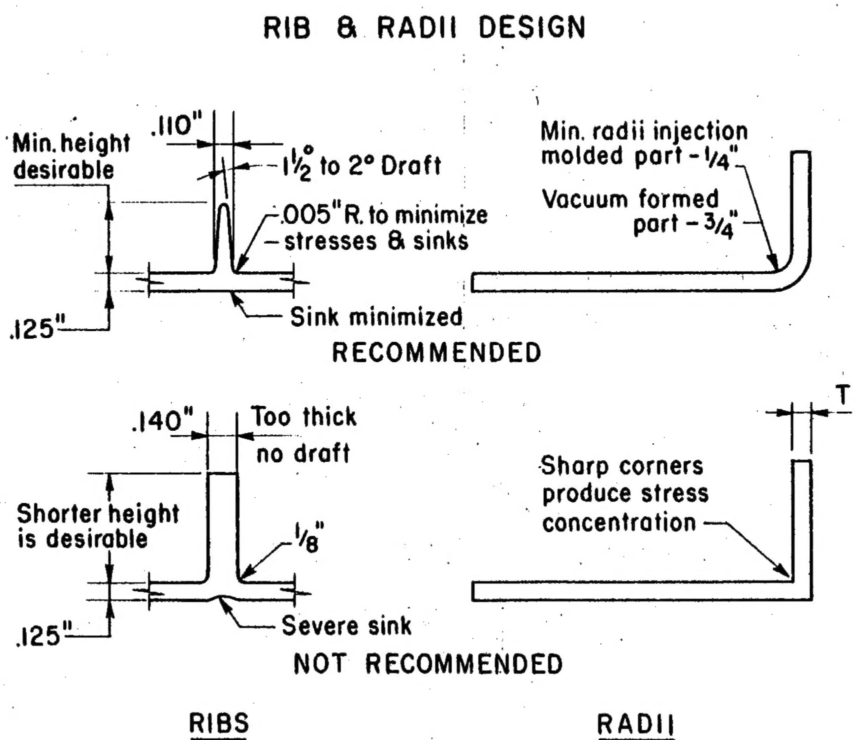

Figure 8

POOR PART DESIGN

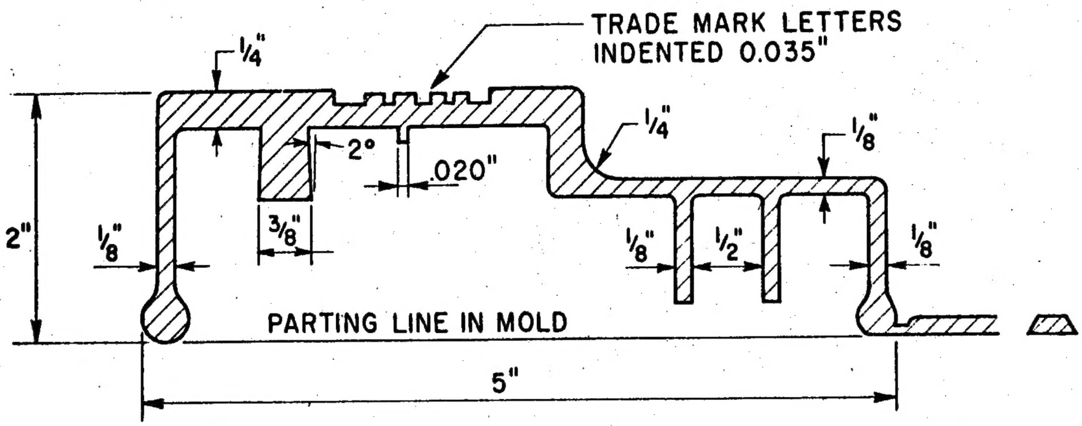

Figure 9

IMPROVED PART DESIGN

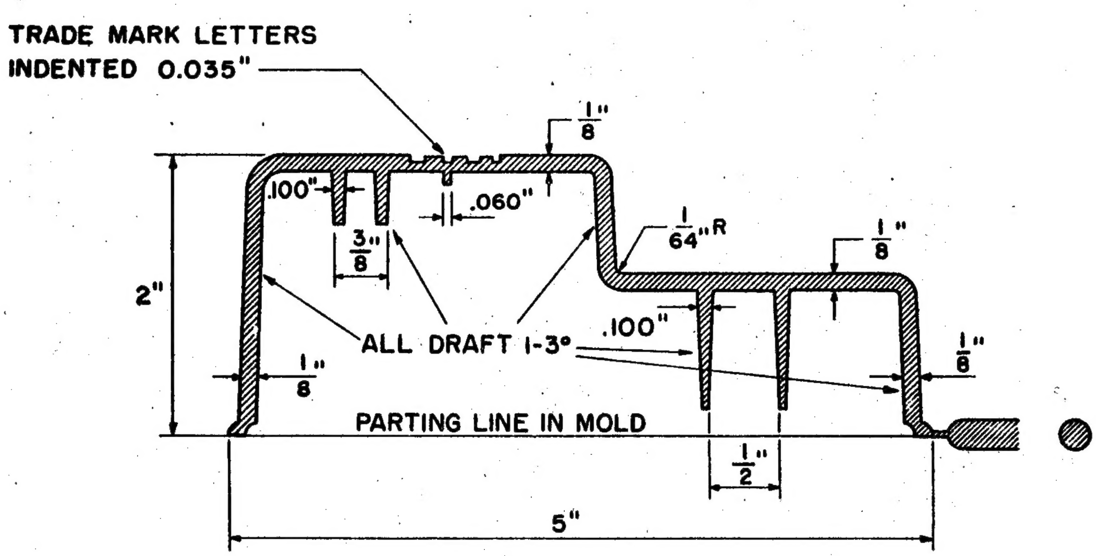

Figure 10

WORK SHEET

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ACCESSION NO. B

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